

Serious Games for ADHD: a narrative review

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Abstract

This article provides an overview of Attention Deficit Hyperactivity Disorder (ADHD) and the effectiveness of Serious Games for ADHD (SGADs) as an intervention. ADHD is primarily characterized by reduced attention and impulsivity, which significantly hinder normal development in children. These core symptoms can affect various aspects of a child's life, including academic performance, social interactions, and overall well-being. Literature data indicate that ADHD is highly prevalent among children, affecting millions globally, and SGADs are emerging as a promising and effective intervention. The interactive and engaging nature of these games offers a novel approach to managing ADHD symptoms, making treatment more appealing to children who may otherwise resist traditional therapies. In this article, a literature review will be presented on SGADs, focusing specifically on potential video games and platforms useful for the diagnosis and treatment of ADHD in children. The review will examine various studies and clinical trials that have explored the efficacy of SGADs, highlighting how these games leverage technology to provide real-time feedback, personalized treatment, and engaging experiences. By analyzing different video games and platforms, the review aims to identify key features that make these tools effective for ADHD intervention. This includes the use of brain-computer interfaces, motion sensors, and adaptive learning algorithms that adjust the game's difficulty based on the child's performance, thereby maintaining an optimal level of challenge and engagement. Finally, there is a discussion with potential suggestions for future research directions based on the current state of SGADs. This discussion will explore gaps in the existing literature, such as the need for long-term studies to assess the sustained impact of SGADs on ADHD symptoms. It will also consider the potential for developing new game-based interventions that target specific cognitive and behavioral aspects of ADHD. Suggestions for future research may include the integration of advanced technologies like virtual reality and augmented reality to create more immersive and interactive therapeutic environments. Additionally, the discussion will address the importance of tailoring these interventions to the individual needs of children, considering factors such as age, gender, and the severity of symptoms. By proposing these directions, the article aims to pave the way for more comprehensive and effective solutions for managing ADHD through serious games.

Keywords

ADHD, serious games, systematic review, diagnosis, treatment.

1. Attention Deficit Hyperactivity Disorder (ADHD)

Attention Deficit Hyperactivity Disorder (ADHD), also known as hyperactivity, is primarily characterized by symptoms related to inattention, impulsivity, and hyperactivity. The prevalence of ADHD generally stands at around 7.2%, although this may vary depending on different diagnostic criteria [1]. ADHD is more prevalent in boys than girls, indicating that many children experience this condition [2]. Children with ADHD struggle to focus, maintain attention, and resist distractions due to attention deficits. Additionally, the hyperactivity disorder contributes to poor inhibition, leading to challenges in emotion and behavior management, increasing the likelihood of impulsivity. ADHD symptoms create significant disadvantages in children's daily lives, negatively impacting academic performance, limited concentration in class, and a heightened risk of school dropout [3]. Furthermore, obstacles in language expression and reading comprehension often

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manifest, posing detrimental aspects to their normal growth [4, 5]. Other difficulties may arise in social relationships, as children may exhibit extreme behaviors such as conflicts with family and friends, and they may be more predisposed to developing other mental conditions, including oppositional defiant disorder and depression [6].

The traditional approach to ADHD treatment through medication can lead to dependence and generate side effects [7]. A new approach to ADHD treatment is provided by emerging technologies: serious games, designed to blend entertainment and education, offering various technological solutions and intervention methods [48].

In literature, with reference to Serious Games for ADHD (SGAD), games on consoles, computers, and mobile devices have been explored. Somatosensory technology in console games facilitates physical interaction, making exercise enjoyable for ADHD patients. Computer games, focused on therapy, utilize Brain-Computer Interface (BCI) technology to detect EEG and facilitate attention training. Sung has proposed a simplified framework for developing BCI-based serious games [8]. A systematic review conducted by Zung et al. (2021) explores the crucial role of serious games in the diagnosis and treatment of ADHD, recognizing them as a fundamental resource for managing the condition and offering a promising perspective for addressing the disorder. While structured questionnaires and interviews are commonly used for patient assessment, these methods can be influenced by subjective opinions, compromising the reliability of the diagnosis [9]. In hospital settings, children with ADHD may struggle to naturally exhibit symptoms, complicating diagnosis. Serious games address this challenge by involving users in an immersive environment, using interactive technology and multisensory experiences to enhance the effectiveness of assessment [10]. In this sense, gamified assessment facilitates participant engagement, reducing energy expenditure and dropout rates during the process, proving more appealing than traditional methods [11]. Particularly in the treatment of ADHD with serious games, improvements are observed in the development of daily and social skills, as well as in attention and impulse management. The use of serious games as a complementary tool not only alleviates symptoms but also enhances executive functions and provides cognitive training [12].

2. Serious games and ADHD

Serious games, defined as games with purposes beyond mere entertainment, have achieved notable success in fields such as the military, education, and medicine due to their educational effectiveness [13]. The constant stimulation and timely feedback provided by video games enable children with ADHD to sustain attention for longer periods during play [14]. The therapeutic journey through serious games allows ADHD patients to actively participate in the treatment process, completing the educational path smoothly and efficiently. Video games create an engaging environment, presenting stimulating challenges that significantly amplify players' enthusiasm [15]. In terms of diagnosis and treatment, the systematic review conducted by Zheng et al. (2021) on Serious Games for ADHD (SGAD) thoroughly examined the gaming mechanism and operational methods of each game, providing an overview of the specific outcomes that such games can achieve. For instance, console games allow for more natural interaction, enabling players to operate through body movements rather than just buttons [48]. Some studies in the literature demonstrate that the use of SGAD can increase the enthusiasm of children with ADHD to participate in treatment and improve the effectiveness of executive function training [16]. Chuang's study on the effect of Wii console games on children with ADHD highlighted an increase in fun and attention during gameplay. Children with ADHD find SGAD to be an effective way to train specific deficits in executive functions [17]. Benzing's experiment on the use of Shape UP and Beatmaster Training Quest, via the Microsoft Xbox console, demonstrated that exercise games contribute to improving executive function deficits, and more importantly, reduce inhibition and enhance readiness in patients with ADHD [18]. Significant improvements in attention and daily skills in children with ADHD have also been demonstrated by computer games. Specifically, a correlation between attention levels and brain waves has been shown in the literature; in this regard, Brain-Computer Interface (BCI) technology has been introduced in computer-based SGAD, allowing direct communication between the brain and the computer. The EEG apparatus collects brain signals, integrating them directly into computer activity and eliminating the need for traditional input devices such as a mouse or

keyboard [19]. A study conducted on children with ADHD confirmed the effectiveness of neurofeedback in mitigating ADHD symptoms. Through the use of BCI devices, neurofeedback monitors brain activities during video games, providing instant feedback and facilitating the improvement of brain waves [20, 21, 22]. A meta-analysis demonstrated that various factors, such as the depth of treatment, assessment reports, and the EEG equipment used, have been identified as variables that can influence the effectiveness of neurofeedback therapy [23]. With the advancement of technology, virtual reality has also made significant contributions in this field. Serious games based on this technology can create an engaging environment, facilitating the transfer of learned skills from training to real-life situations. Through a controllable reality environment, cognitive exercises and timely feedback are offered, contributing to the improvement of ADHD symptoms, enhancing players' responsiveness and sensitivity during gameplay, and facilitating proper integration into the training environment [24, 25] (see Table 1).

Table 1.
Overview of Serious Games for ADHD

Field	Details
Definition	Serious games are games with purposes beyond mere entertainment, achieving success in fields such as the military, education, and medicine.
Effect on children with ADHD	Provide constant stimulation and timely feedback, helping children with ADHD maintain attention for longer periods.
Therapeutic participation	Serious games allow ADHD patients to actively participate in the treatment process, completing the educational path smoothly and efficiently.
Engagement and challenges	Create an engaging environment with stimulating challenges, significantly increasing players' enthusiasm.
Diagnosis and treatment	Zheng et al. (2021) examined the gaming mechanisms and operational methods of Serious Games for ADHD (SGAD). Console games allow for natural interaction through body movements.
Effectiveness	Studies show that SGAD can increase the enthusiasm of children with ADHD for treatment and improve executive function training.
Wii console	Chuang's study highlights an increase in fun and attention in children with ADHD during gameplay.
Xbox (Shape UP and Beatmaster)	Benzing's experiment demonstrates that exercise games improve executive function deficits, reduce inhibition, and enhance readiness in patients with ADHD.
Computer games	Improve attention and daily skills in children with ADHD, correlating attention levels with brain waves.
Brain-Computer Interface (BCI)	BCI technology allows direct communication between the brain and computer, using EEG to integrate brain signals into computer activity. Studies confirm the effectiveness of neurofeedback in mitigating ADHD symptoms.
Effectiveness variables	Treatment depth, assessment reports, and EEG equipment can influence the effectiveness of neurofeedback therapy.
Virtual Reality (VR)	Serious games based on VR create an engaging environment that facilitates the transfer of learned skills to real-life situations, improving

2.1 Serious Games: A tool for diagnosing ADHD

The systematic research conducted by Peñuelas-Calvo has clearly demonstrated the effectiveness of assessment tools based on video games. These innovative tools have shown a remarkable ability to successfully discriminate cases of ADHD from control groups, providing a reliable method for distinguishing between different subtypes of ADHD. This precision in diagnosis is critical, as it allows for more tailored and effective treatment plans. Additionally, video game-based therapies have been positively received and proven effective in improving cognitive functions and reducing ADHD symptoms [26]. This positive reception is crucial as it indicates that both children and their caregivers find these therapies engaging and beneficial, enhancing adherence to treatment protocols.

Gamifying the diagnostic process can make it less monotonous and more engaging and objective since the outcome is based on the children's performance in the game [48]. By transforming what is typically a tedious process into an enjoyable experience, children are more likely to participate willingly and perform to the best of their abilities. This approach also reduces the potential for bias, as the diagnostic outcomes are grounded in the objective measurement of performance metrics within the game environment.

In this regard, Supermarket is an example of a game that uses data mining algorithms to categorize data from children with ADHD and accurately distinguish between children with ADHD and those without ADHD [27]. This game leverages sophisticated data analysis techniques to parse through extensive datasets, identifying patterns and anomalies that correlate with ADHD. The use of data mining algorithms enhances the accuracy of the diagnosis, ensuring that the assessment is both comprehensive and precise.

Another example is the video game developed by Khaleghi [28] for the diagnosis and assessment of ADHD, based on the DSM-IV as a reference diagnostic criterion. In this context, the diagnosis result depends on the analysis of the number of mouse clicks on irrelevant responses, choices made, and the time taken by players. This method provides a detailed behavioral profile of the player, highlighting impulsivity, attention to detail, and decision-making processes, which are critical markers of ADHD.

To assess executive functions, Timo's Adventure has been experimented with, a system composed of six small games with different functions, each aimed at improving specific deficits in executive function. The presence of ADHD is identified based on executive function deficiencies highlighted during gameplay [29]. This multi-faceted approach ensures a comprehensive assessment of various cognitive domains, allowing for a nuanced understanding of the child's executive functioning.

In this context, there are also Serious Games for ADHD (SGAD) based on mobile devices, with an example being the mobile application developed by Nayra that integrates pre-diagnosis and treatment functions for ADHD [30]. The convenience and accessibility of mobile applications make them an excellent tool for ongoing assessment and treatment, providing continuous support and monitoring outside the clinical setting.

Serious games based on brain-computer interaction technologies and virtual reality are employed for ADHD diagnosis [31, 32, 33]. These advanced technologies create immersive environments that engage multiple senses and cognitive functions, providing a rich dataset for assessment. An example is an interactive video game that utilizes Kinect technology to identify player actions, concluding the ADHD diagnosis by evaluating attention. This game allows the player to control the gaming experience through body movement, and attention level is assessed based on variables measured during interaction in the game [34]. The use of Kinect technology enables a natural and intuitive interaction with the game, making the diagnostic process seamless and less intrusive. The attention level is inferred from various metrics such as reaction times, accuracy, and movement patterns, offering a holistic view of the child's attentional capabilities.

By integrating these diverse technologies and methodologies, serious games provide a multifaceted approach to diagnosing and treating ADHD. This approach not only makes the

diagnostic process more engaging for children but also enhances the accuracy and effectiveness of the treatment. As these technologies continue to evolve, they hold the potential to revolutionize the way ADHD is diagnosed and managed, offering new avenues for research and innovation in this field.

2.2 Serious Games: A tool for treating ADHD

The treatment of ADHD through serious games presents itself as a promising perspective, addressing the shortcomings of other therapeutic modalities. Unlike traditional methods that may rely heavily on medication or static forms of therapy, serious games provide dynamic, engaging, and interactive ways to manage ADHD symptoms. By offering a more stimulating environment, they cater to the need for constant engagement and immediate feedback, which are crucial for individuals with ADHD. Through the combined use of various human-computer interaction technologies, the range of interactive experiences is amplified, thereby contributing to improving treatment effectiveness [48]. These technologies, including motion sensors, virtual reality, and adaptive learning algorithms, create immersive experiences that keep the user engaged and motivated. As a result, the therapeutic process becomes more enjoyable and potentially more effective.

Serious games based on brain-computer interface (BCI) are progressively contributing to ADHD treatment, aiming to enhance attention. By integrating EEG devices into the gameplay, these games provide real-time feedback on the player's brain activity, enabling them to adjust their actions based on their current mental state. Through the use of EEG devices, they provide real-time feedback during the gaming experience (via displays or sounds) [35]. This immediate feedback loop helps players become more aware of their attention levels and learn how to modulate them effectively. The continuous monitoring and adjustment can lead to better self-regulation and improved focus over time.

Algorithms, such as frequency analysis, are employed, and some titles incorporate fractal dimension models [36, 37]. These advanced computational techniques allow for a detailed analysis of brainwave patterns, enabling the games to adapt in real-time to the player's cognitive state. For example, in "armis" [38], players use the keyboard to control characters and monitor their brain state through a wireless EEG device. This visual experience allows them to assess the level of attention and regulate it according to the game's requirements. By visualizing their brain activity, players can see the direct impact of their concentration and adjust their strategies accordingly, leading to more effective training sessions.

In another example, a BCI-based video game, set in a 3D virtual classroom, aims to train the player's attention, seeking to transfer the effects of training from simulated situations in games to reality [39]. This simulation of a classroom environment helps players practice focusing in a setting that closely resembles their real-life experiences. By training in such a realistic scenario, players can better apply the skills they develop during gameplay to their daily lives, potentially improving their performance in actual classroom settings.

To exercise attention, patients with ADHD can leverage different types of video games. These games are designed with specific objectives and mechanics that target various cognitive functions. For instance, "Plan it Commander" is a typical serious game that, through three micro games, enhances time management, organizational skills, and social competencies in children with ADHD, demonstrating its utility in rehabilitation [40, 41]. By breaking down complex tasks into smaller, manageable mini-games, "Plan it Commander" makes learning new skills fun and accessible. Each micro game focuses on a different aspect of executive function, ensuring a comprehensive approach to skill development.

Other games like "Braingame Brian" and "Antonyms" aim to improve attention and executive function, contributing to the voluntary engagement of patients in treatment [42, 43]. These games use a variety of techniques to capture and maintain the player's interest, such as rewarding progress and offering increasingly challenging tasks. This not only helps improve cognitive functions but also encourages children to participate actively in their treatment.

In relation to executive functions, Wrońska has developed a serious game to improve reading comprehension related to memory [44]. This game targets specific aspects of cognitive function that

are often challenging for individuals with ADHD. By focusing on reading comprehension and memory, it helps players develop essential skills that are crucial for academic success.

Additionally, "The Secret Track of the Moon" offers a realistic chess-based gaming experience and uses virtual reality to provide cognitive training to patients with ADHD [45]. By combining the strategic elements of chess with the immersive nature of virtual reality, this game provides a unique and engaging way to train cognitive functions. Players can practice critical thinking, problem-solving, and planning in a highly interactive environment.

Finally, among the most innovative therapeutic approaches for children with ADHD, strategies aimed at reducing stress and promoting emotional regulation through breathing exercises proposed by "Chillfish" using LEGO respiratory sensors emerge [46]. These exercises help children learn how to manage their stress and emotions, which can be particularly beneficial for those with ADHD. By integrating these exercises into a playful and familiar context, "Chillfish" makes it easier for children to adopt these techniques.

To improve attention and inhibit impulses, "ADDventurous Rhythmical Planet" uses musical rhythm, also fostering cooperation between children with ADHD and other players [47]. The use of music and rhythm in this game helps children develop better self-control and timing, while the cooperative gameplay encourages social interaction and teamwork. This multifaceted approach addresses both cognitive and social aspects of ADHD, providing a holistic treatment experience.

3. Conclusion

In conclusion, based on the meta-analyses examined, there appears to be a particular effectiveness of Serious Games in the treatment of ADHD. These analyses suggest that serious games offer a unique advantage over traditional methods by making the diagnosis and treatment process more engaging for children. This engagement is crucial as it can significantly reduce ADHD symptoms, thereby enhancing the overall quality of life for these children. The interactive and immersive nature of serious games captivates children's attention, which is often a challenge in conventional therapy settings.

The use of various technologies, such as EEG detection and human-computer interaction, allows for accurate assessment and adaptation of treatment to the specific needs of patients. EEG detection enables real-time monitoring of brain activity, providing immediate feedback that helps tailor the gaming experience to the player's current cognitive state. This precise feedback mechanism ensures that the treatment is continually adjusted to meet the evolving needs of the patient, leading to more effective outcomes. Human-computer interaction technologies, such as motion sensors and adaptive algorithms, further enhance the customization of these games, ensuring that each child receives a personalized therapeutic experience.

These games play a significant role in supporting children with ADHD in enhancing attention, improving executive functions, and strengthening social communication skills. By providing structured yet flexible environments, serious games help children practice and develop crucial cognitive skills in a fun and motivating way. Enhancing attention through engaging gameplay helps children stay focused on tasks for longer periods, a skill that can translate to better performance in academic and daily activities. Improving executive functions, such as planning, organization, and impulse control, prepares children to handle complex tasks more effectively. Furthermore, the social aspects of many serious games encourage children to interact with peers, fostering better communication and teamwork skills, which are vital for their social development.

However, they are not without critical aspects, such as the risk of video game addiction and the need to customize approaches based on the individual characteristics of patients [48, 49, 50]. The engaging nature of serious games, while beneficial, also poses the risk of excessive use or addiction, which could negate the positive effects of the treatment. It is essential for caregivers and therapists to monitor usage and ensure a balanced approach to gaming. Additionally, the effectiveness of serious games can vary significantly based on individual differences among patients. Factors such as age, severity of symptoms, and personal interests must be considered when designing and implementing these games to maximize their therapeutic potential.

Finally, possible future directions for research on this topic are suggested. Future studies could explore the long-term effects of serious games on ADHD symptoms to determine their

sustainability and potential for integration into standard treatment protocols. Research could also investigate the development of new technologies and game mechanics that further enhance the therapeutic benefits of serious games. Additionally, studies focusing on the prevention of video game addiction and the creation of guidelines for safe and effective use are essential to ensure the responsible implementation of these tools in clinical practice. By addressing these areas, the field can continue to evolve, offering innovative and effective solutions for managing ADHD.

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